PREHARVEST SEEDBED PREPARATION OPTIONS TO ENHANCE LOBLOLLY PINE REGENERATION [1]

Dale Wade, M. Boyd Edwards, and David R. Weise [2]

Abstract. Pine establishment and vegetative competition recovery were observed after combinations of single prescribed burns and herbicide applications just prior to harvest of the pine in a mixed pine-hardwood stand. Four growing seasons after harvest, all treatments resulted in adequate stocking of free-to-grow seedlings. Pine distribution was very uneven on all unburned treatments. Species composition was not affected. Sweetgum was the dominant hardwood species both before and after harvest. Common associates were flowering dogwood, red oaks, black cherry, and winged elm. Herbaceous plants dominated the area for a few years after harvest. Indications are that vines will again dominate the surface vegetation as they did prior to harvest.

Introduction

Privately-owned tracts smaller than 100 ac comprise about 70 percent of the South's commercial timberland. Many of these small nonindustrial private forest (NIPF) landowners lack the desire, or the capital resources necessary to establish pine plantations. All too often these landowners harvest the highly salable pine component of their mixed pine-hardwood stands without regard for future species composition of the overstory. On the Piedmont Plateau, stands developing after logging cannot be counted on to contain large numbers of high-value pine without additional treatment. Residual low-value hardwoods capture the site at the expense of the less shade-tolerant pine. An extensive literature base (e.g., Korstian and Coile 1938; Chen et al., 1977; Glover and Dickens 1985) describes the reduction in growth of pine reproduction due to hardwood competition for sunlight, moisture, and nutrients.

We agree with Clason (1989) that implementation of a reforestation plan is the most crucial step in managing a timber stand. Many pre- and postharvest techniques are available for establishing pine. The level of treatment intensity chosen should be dictated by specific onsite conditions, but in practice the cheapest alternative is often chosen. Prescribed fire is the traditional "low tech" treatment. However, if a significant hardwood midstory is present, preharvest dormant-season fires by themselves are generally ineffective because they are not likely to topkill hardwoods over 3-4 inches in diameter. If natural regeneration is to be relied on to reestablish the pine compon-

[1] Paper presented at Sixth Biennial Southern Silvicultural Research Conference, Memphis, TN, Oct. 30-Nov. 1, 1990.

[2] Research Forester, Research Ecologist, Southeastern Forest Exp. Sta., Macon, GA; and Forester, Pacific Southwestern Forest Exp. Sta., Riverside, CA.

ent, another disadvantage of preharvest winter burns is that they give hardwood rootstocks a full growing season to recover before the next seed crop is available. Some combination of fire and mechanical or chemical treatment therefore, is generally recommended. A fire prior to seedfall is attractive because it does not destroy the maturing cone crop, whereas a fire after seedfall or clearcutting destroys the pine seed crop along with any advance regeneration. This necessitates the additional task of seeding or planting the area, making this option more costly to the landowner. The economic benefits of low-cost pine regeneration alternatives have been described by Edwards and Dangerfield (1990).

NIPF landowners often minimize costs by controlling hardwoods themselves. Their options are pretty much limited to prescribed fire, herbicides, or some combination of the two, because they generally do not have access to heavy mechanical equipment such as drum choppers. A major reason small landowners choose preharvest techniques is because they can time the harvest cut to take advantage of the standing cone crop to restock the area. If "enough" vigorous advance reproduction is present, chemical treatment of the broadleaved vegetation has a decided advantage over other choices.

In this paper, we describe pine establishment after low-intensity summer fire, herbicide applied at minimum recommended rates, and combinations of the two. Treatments were imposed before the pine component of a mixed pine-hardwood stand was harvested. Postharvest treatments were compared in a companion study conducted on a nearby site (Bramlett et al., this volume). Early results of these two studies show why landowners who want to promote fiber production are often willing to invest larger sums of money per acre to site prepare and plant.

Methods

The study site was a 90-ac, economically mature, pine-hardwood stand on the Lower Piedmont in Jones County, Georgia, approximately 40 mi north of Macon. No evidence of past fire or previous cultural measures was noted. The pine component was scheduled for harvest after the 1986 seed fall. Specific objectives were to: (1) determine the feasibility of low-intensity summer burns and the ease of fire containment after chemical treatment of the hardwood component; (2) document the recovery of broadleaved vegetation; (3) compare the survival, height, and competitive position of the pine regeneration established after various treatments; and (4) determine whether the order of application of treatment combinations affected objective three.

Eighteen 1.6-ac study plots were installed in a completely randomized design during the spring of 1986 to accommodate three replications of each of six treatments. Stream bottoms and lower slopes where hardwoods predominated were avoided. The following treatments were randomly assigned: (1) burn only (BO); (2) herbicide only (HO); (3) burn and herbicide (BH); (4) herbicide and burn (HB): (5) late-season herbicide (LH); and (6) control (CN). During the summer of 1986 before treatment application, vegetation less than 4.5 ft tall that originated below groundline on the sample area was tallied along a 300- by 2-ft (600 ft^2) belt transect diagonally bisecting each plot. Vegetation over 4.5 ft tall was tallied along an overlying 300- by 20-ft belt transect encompassing 6,000 ft^2 of each plot.

We found the study area to be floristically diverse. (Individual species are listed in Appendix 1.) Considerable variation was noted in understory amount and stature, and in the ratio of pine to hardwood in the overstory. We attribute much of this variation to a southern pine beetle outbreak in the early '80s. Most of the dead pines were on the ground in 1986.

Herbicide Application

Herbicides were applied during the first week of August or during mid-October. Hardwood stems under 3 inches dbh were stem sprayed with a mixture of 10 percent Garlon 4™, 10 percent Cide-Kick™, and 80 percent diesel fuel using a backpack sprayer. This type of application is commonly referred to as a "thin line" treatment. Hardwoods larger than 3.5 inches dbh were treated with a hypohatchet containing Tordon RTU™.

The amount of Garlon 4 applied ranged from 0.25 to 2.2 and averaged 1.5 pt/ac. The amount of Tordon RTU used ranged from 0.62 to 1.6 and averaged 1.0 pt/ac. Total time to apply both herbicides ranged from 1.25 to 3.4 and averaged 2.5 hr/ac. Use of minimum recommended herbicide concentrations in "thin line" applications, spacing greater than 1 inch between frills in the hypohatchet operation, poor translocation because of severe drought (which lasted into 1989), and/or some stems being missed resulted in incomplete kill of the hardwood midstory and overstory. The fall 1986 survey of herbicide-only, late herbicide, and herbicide-burn plots showed 15 percent of the 648 hardwoods were defoliated while 44 percent showed no signs of herbicide effect. A followup survey in September 1990 showed an average of 14 (5 to 36) midstory hardwoods/ac were still alive on these plots. Over half of these survivors were sweetgum. The next most common survivor was flowering dogwood, which comprised 8 percent of the total.

Prescribed Fires

Dead fuels on the ground were collected on four ¼ milacre subplots in each of the nine treatment plots scheduled for burning, and separated into the following six categories: upper litter layer, duff, twigs less than ¼ inch, twigs ¼ to ½ inch, branches ½ to 1 inch in diameter, and cones. Weight of dead fuels before burning averaged 3.5 and ranged from 2.6 to 4.4 tons/ac (SE 0.14 to 0.55).

The plots were headfired over a 2-day period in September. Our original intent was to burn 4 weeks after herbicide application, but desiccation of the broadleaved foliage did not occur as rapidly as anticipated, so we delayed burning until September 26 and 27, 1986. Linefires were ignited across the lower side of each plot so that they would burn upslope. Three of the plots were eventually ring-fired to ensure burnout before nightfall. Onsite ambient temperature was between 83 and 89°F and relative humidity between 49 and 69 percent during the burns. Within-stand winds were generally light (0 to 1) and variable. Moisture content of the upper litter layer immediately prior to ignition ranged from 10 to 25 percent. The Keetch-Byram Drought Index stood at 457, suggesting that damage to tree feeder roots should be expected. The fires covered over 95 percent of all but two plots. Rate of spread averaged 1 to 2 ft/min and flame length 0.5 to 1.0 ft. Byram's (frontal) fireline intensity, calculated using consumption data, was very low ranging from 10 to 15 Btu/ft/sec.

Fuels were resampled in the manner described the week after the burns. Consumption of dead fuels ranged from 0.9 to 3.0 tons/ac. In the six fuel categories, consumption ranged between 23 and 61 percent and averaged 55 percent. Two of the nine plots scheduled to receive a fire treatment were dropped from the study because of treatment application problems. One of the plots simply would not burn and the burn on the other was very patchy, covering less than 50 percent of the area. Few overstory pines remained on these two plots after the southern pine beetle outbreak of the early 1980s. As a result, pine litter was insufficient to carry fire under the existing weather conditions.

Hardwood crown damage from both the herbicide and fire treatments was also surveyed the week after the burn. The following week the same herbicide treatment used earlier was applied to the burn-herbicide and late herbicide plots. Logging began immediately after this herbicide application and was completed during November 1986.

Cone Survey

Few maturing cones were noted during the summer of 1986, so we conducted a binocular survey following the methodology suggested by Webb and Hunt (1965). Seed production was estimated to be nonexistent on 9 of the study plots. On the other 9 plots, it ranged from less than 1,000 to 17,500 seeds/ac. Based on this survey, we decided to artificially seed the study area the following spring.

Direct Seeding

All plots were seeded with a mixture of 80 percent treated and stratified and 20 percent untreated and unstratified loblolly pine seed. Seeds were sown at a rate of 1 lb/ac with a cyclone seeder on April 6, 1987. Within plots, seeds were disseminated by first walking the diagonal belt transect midline and then attempting to evenly spread half the remaining seeds on each side of this diagonal.

Response Variables

Advance pine reproduction and germinants were flagged and followed over the next three growing seasons along reestablished 600 ft^2 belt transects that diagonally bisected each plot. Recruitment, survival and height were measured. The likelihood of each seedling eventually becoming part of the overstory was judged using the Virginia Division of Forestry Free To Grow (FTG) classification (Zutter et al., 1984). In this scheme, a 1 denotes a better than 90 percent chance that a seedling or sapling will capture a place in the overstory. A 4 denotes less than a 10 percent chance of reaching the crown canopy. Treatment means were compared by analysis of variance (ANOVA) at the 0.05 level of statistical significance.

Hardwood recovery was monitored for the first 2 years after treatment along the same transects used in the pine surveys. Importance Values (IV) were calculated based on the relative frequency, density, and dominance (basal area) of a species compared to those of all other species using Ohmann (1973) as a guide. Herbaceous plants and shrubs were also measured for two growing seasons after treatment on eight 7.0-ft diameter subplots randomly located along each belt transect.

Results And Discussion

Vegetation Before Treatment

Vegetation Taller Than 4.5 Feet: Twenty-five species groups were tallied in the pretreatment survey of vegetation taller than 4.5 ft. Pine (predominantly loblolly with some shortleaf) basal area ranged from 52 to 81 ft^2 and comprised from 61 to 83 percent of the 92 ft^2 total basal area/ac (Table 1). Sweetgum was the major hardwood midstory species on all but one treatment plot. Its basal area averaged 12 and ranged from 7 to 18 ft^2/ac. Red oaks (primarily water and southern red) and hickory each had a basal area above 9 (13 and 10 ft^2, respectively) on one treatment plot. All other species had basal areas averaging less than 5 ft^2/ac.

Pine occurred in 70 percent of the 400 subplots. Sweetgum and flowering dogwood occurred on 43 percent, red oaks on 20 percent, elm (primarily winged) on 12 percent, and vines (muscadine grape on 40 percent, Japanese honeysuckle on 36 percent, greenbriars on 34 percent) on 74 percent of the subplots.

All other species over 4.5 ft tall occurred on less than 10 percent of the subplots. Number of stems/ac over 4.5 ft tall averaged 2,742 and ranged from 2,422 to 3,121 on the six treatment areas. Pine averaged 852 stems/ac and dominated on all but one treatment plot where it was the second most numerous species behind sweetgum. Flowering dogwood, sweetgum, muscadine grape, honeysuckle, and greenbriars were the most common broadleaved plants. Pine density exceeded 1,000 stems/ac on two treatments and 500 stems/ac on five of the six treatments. Sweetgum numbers exceeded 500/ac on the herbicide-only treatment plots.

Based on the characteristics evaluated, pine was the most important tree species group before treatment. Its importance value (IV) was at least triple that of any other arborescent species group (Table 1). Sweetgum and flowering dogwood were the dominant broadleaved species on most plots. Red oaks, maple, hickory, cherry (primarily black), elm, Japanese honeysuckle, greenbriar, and muscadine grape were also important hardwood midstory species groups.

Vegetation Shorter Than 4.5 Feet: Before treatment an average of 79,798 (69,822 to 97,381) plants/ac less than 4.5 ft tall were present. They were placed in 21 species groups. Vines were the most abundant species group, comprising 64 percent of this total. Herbaceous plants were the second most numerous species group on four of the six treatments averaging 7,780 stems/ac. Flowering dogwood was the most abundant hardwood with 6,857 stems/ac. Stocking of small pines averaged 4,762 stems/ac, but few of these overtopped seedlings would be expected to survive the rigors

Table 1. Descriptors of major plant species groups, 1986 pretreatment survey. Means of 16 plots.

Species	Density (ft) > 4.5	Density (ft) < 4.5	Basal area	Stocking (ft) > 4.5	Stocking (ft) < 4.5	Importance value > 4.5 ft	Subplots dominated by < 4.5 ft
	----- Stems/ac ----		ft²/ac	---- percent ----			- percent -
Maple	19	582	<1	03	15	0.033	0
Hickory	29	153	2	06	07	0.074	0
Flowering dogwood	407	6,857	3	43	61	0.410	04
Persimmon	<1	68	<1	<1	03	0.017	0
Herbs	0	7,780			68		04
Sweetgum	327	3,205	12	43	51	0.584	01
Pine	852	4,762	66	70	74	1.918	0
Black cherry	31	1,226	1	07	36	0.066	<01
Red oaks	96	2,355	4	20	55	0.209	0
Winged elm	51	29	2	12	02	0.100	0
Vines	865	51,163	<1	74	99	1.162	91
Mean, all species	2,742	79,798					

of competition and make it into the crown canopy. Vines occurred in virtually all of the 400 subplots, pine in 74 percent, herbs in 68 percent, flowering dogwood in 61 percent, red oaks in 55 percent, and sweetgum in 51 percent of the subplots.

The results of these surveys confirm that vegetation was dense (over 80,000 stems/ac). Pine occurred in 92 percent of all subplots, dominated the overstory, and shared the midstory with sweetgum, flowering dogwood, and red oaks (Table 2), while vines were a major component of both the midstory and understory.

Vegetation after Treatment

Advance Reproduction: Live and dead pine seedlings were tallied and flagged in June of 1987 along the 300- by 2-ft belt transect in each plot. Pines at least 1-year old but less than 4 ft tall were differentiated from new germinants. As expected, surviving advance regeneration was sparse on the seven burned plots, averaging 60 stems/ac. The six unburned plots treated with herbicide contained an average of 230 seedlings, and the controls 218 seedlings/ac (Table 3).

In fall 1989, 642 seedlings/ac were still alive. Most were in the herbicide-only and late herbicide treatment plots. Fifty-six percent of the survivors were in FTG categories 1 and 2. An average of 24 seedlings/ac survived on the three burn treatments, all in FTG category 1.

Pines Established after Treatment: Spring 1987 germinants that survived their first growing season averaged 1,276 stems/ac (Table 4). This number ranged from 315/ac (of which 193 were in FTG category 1) on the

Table 2. Density, percent stocking, and importance value of major arborescent species groups, by treatment by year.

	Treatment* BH	BO	CN	HB	HO	LH	Mean	IV
	Stems/ac (Percent stocking)							
Pretreatment, 1986								
Maple	73(04)#	298(12)	660(21)	832(27)	1,554(29)	186(16)	600(14)	
Hickory	131(14)	160(12)	190(20)	220(19)	302(13)	85(09)	181(16)	
Flowering dogwood	10,509(86)	8,465(78)	2,959(71)	7,764(64)	10,263(89)	3,625(53)	7,264(74)	
Persimmon	36(02)	0	82(04)	194(11)	0	99(03)	69(03)	
Sweetgum	3,351(70)	1,150(48)	3,269(91)	3,727(79)	5,946(85)	3,744(71)	3,532(74)	
Pine	5,503(94)	5,380(84)	5,456(94)	5,973(99)	5,726(95)	5,646(85)	5,614(92)	
Black cherry	1,165(54)	1,006(42)	1,097(41)	1,225(48)	1,384(39)	1,067(37)	1,157(44)	
Red oaks	3,460(76)	2,842(86)	2,103(65)	2,328(49)	2,393(60)	1,518(53)	2,452(65)	
Winged elm	33(18)	80(28)	121(27)	17(09)	227(37)	05(11)	80(22)	
Post treatment, Fall 1987								
Maple	36(17)	0	994(75)	121(33)	278(56)	218(22)	274(34)	0.084
Hickory	109(67)	563(67)	122(50)	109(33)	133(33)	97(56)	189(51)	0.164
Flowering dogwood	762(100)	1,234(83)	1,102(88)	666(89)	1,742(100)	1,101(89)	1,101(92)	0.505
Persimmon	254(100)	200(83)	54(25)	109(67)	48(33)	242(67)	151(62)	0.106
Sweetgum	3,775(100)	3,158(100)	3,062(100)	2,735(100)	1,718(89)	1,912(89)	2,728(96)	0.681
Pine	526(100)	599(100)	884(75)	411(67)	569(67)	363(78)	559(81)	0.353
Black cherry	889(100)	653(83)	749(100)	242(78)	762(89)	750(78)	674(88)	0.314
Red oaks	1,506(100)	1,307(100)	1,578(100)	726(89)	2,009(100)	1,016(100)	1,357(98)	0.377
Winged elm	436(83)	436(67)	286(62)	60(33)	714(100)	121(56)	342(67)	0.122
Post treatment, Fall 1988								
Maple	0	0	1,225(62)	73(11)	254(56)	194(33)	291(27)	0.082
Hickory	54(33)	272(67)	150(38)	73(44)	24(22)	12(11)	98(36)	0.139
Flowering dogwood	399(100)	1,125(83)	708(88)	762(89)	1,222(100)	895(89)	852(91)	0.283
Persimmon	0	36(33)	54(25)	36(33)	12(11)	24(22)	27(21)	0.032
Sweetgum	2,269(100)	1,996(100)	2,627(100)	2,130(100)	1,718(100)	1,512(100)	2,042(100)	0.953
Pine	690(100)	1,143(100)	925(100)	1,234(100)	1,186(100)	690(100)	978(100)	0.574
Black cherry	363(100)	345(83)	299(75)	97(56)	532(100)	593(78)	372(82)	0.169
Red oaks	1,125(100)	926(100)	1,020(100)	726(89)	1,621(100)	786(89)	1,034(96)	0.324
Winged elm	254(83)	381(50)	231(50)	36(33)	411(79)	73(78)	231(62)	0.155

* Treatment abbreviations explained in the methods section.

\# Number of stems is first number with percent stocking in parenthesis. Stocking based on twenty-five 24 and 240 ft^2 subplots/plot in 1986, and on three 400-ft^2 subplots per plot in 1987 and 1988.

late-herbicide plots to 1,765/ac (532 were in FTG class 1) on the herbicide-burn plots. A year later, survival of these seedlings ranged from 32 percent on the late-herbicide plots to 85 percent on the herbicide-burn plots (Table 5). Duncans multiple range test with arcsine-transformed survival data indicated that survival was significantly better on herbicide-burn plots than survival on the herbicide-only and late-herbicide plots.

Table 3. Advance pine regeneration on a per-acre basis by free to grow class and treatment by year.

Treatment*	FTG class 1	2	3	4	Total
	-- (Seedlings/ac) --				
Fall 1987					
BH	0	36	0	36	72
BO	36	0	36	36	108
CN	82	82	27	27	218
HB					0
HO	24	0	24	0	48
LH	218	145	48	0	411
Total	360	263	135	99	858
Fall 1988					
BH					0
BO	36	36	0	0	72
CN	0	82	27	0	109
HB					0
HO	0	24	24	0	48
LH	97	97	145	0	339
Total	133	239	196	0	568
Fall 1989					
BH					0
BO	72	0	0	0	72
CN	54	0	27	0	81
HB					0
HO	97	48	48	97	290#
LH	54	36	0	109	199
Total	277	84	75	206	642

* Treatment abbreviations explained in the methods section.

\# Apparent increase in number of seedlings/ac is due to change in blow-up factor because of loss of one treatment plot between 1988 and 1989 surveys.

In the 1989-1990 dormant season survey, dead or missing pines were not tallied and new recruits were recorded as existing pines, so percent survival could not be determined. New germinants continued to show up on all but the late-herbicide plots. These recruits occurred mainly along the uncut forest edge. By fall 1989, all postharvest seedlings on the late-herbicide plots had died (Table 4). Excluding that treatment, the number of seedlings judged to have a good chance of becoming overstory canopy trees (FTG classes 1 and 2) ranged from 146/ac on the control plots to 583/ac on the herbicide-burn plots. Results after 3 years show that all treatments-- except the late-herbicide and control-- produced over 425 free-to-grow pines/ac. Combining new recruit and advance regeneration data indicates a sufficient number of pine seedlings were produced on all treatments to assure that this species will again dominate the overstory of the developing stand.

Although no pine seedlings were tallied on the late-herbicide plot transects in 1989, numerous seedlings were observed elsewhere on these plots. In September 1990, we therefore evaluated pine regeneration on three 1/100-ac subplots established along the opposing diagonal of every plot (Table 4). Pine recruitment was still taking place on all treatments. The maximum number of first-year germinants tallied was 211/ac on the herbicide-burn treatment plots. A few pines judged to have been established prior to treatment were found on herbicide-only and control plots. Excluding both advance reproduction and new germinants, this supplemental survey showed that pines likely to comprise the developing overstory (FTG classes 1 and 2) were most numerous on the late-herbicide treatment plots (950), and least numerous on the herbicide-only treatment plots (233).

Table 4. Mean pine density and height by treatment and free to grow class.

Treatment *	FTG class								Total density
	1		2		3		4		
	Density	Height	Density	Height	Density	Height	Density	Height	
	stems/ac	ft	stems/ac	ft	stems/ac	ft	stems/ac	ft	stems/ac
Fall 1987									
BH	363	0.35	544	0.40	436	0.37	0		1,343
BO	690	0.45	472	0.38	326	0.24	218	0.20	1,706
CN	218	0.55	424	0.18	218	0.32	145	0.21	1,005
HB	532	0.34	798	0.20	411	0.16	24	0.10	1,765
HO	49	0.27	823	0.38	532	0.41	121	0.30	1,525
LH	193	0.32	73	0.08	49	0.27	0		315
Mean		0.38		0.27		0.30		0.20	1,276
Fall 1988									
BH	581	0.74	363	0.56	36	0.55	36	0.35	1,016
BO	544	0.79	254	0.57	97	0.21	218	0.35	1,113
CN	145	0.62	351	0.72	314	0.41	121	0.16	931
HB	726	0.58	774	0.67	24	0.10	49	0.27	1,573
HO	97	0.72	436	0.98	363	0.52	169	0.65	1,065
LH	97	0.70	49	0.40	24	0.16	24	0.20	194
Mean		0.69		0.65		0.32		0.33	982
Fall 1989									
BH	472		73		36		254		835
BO	326		109		109		472		1,016
CN	85		61		36		617		799
HB	559		24		243		678		1,500
HO	290		254		218		617		1,380
LH	0		0		0		0		0
Mean									922
Fall 1990 #									
BH	450		383		317		50		1,200
BO	283		433		567		150		1,433
CN	222		289		311		233		1,055
HB	267		600		1,033		600		2,500
HO	33		200		284		400		916
LH	400		550		367		300		1,616
Mean									1,453

* Treatment abbreviations explained in the methods section.

Supplemental survey based on three 1/100-ac subplots per plots. Numbers exclude first year germinants.

We attribute the large differences in seedling numbers between the two surveys to seedling distribution patterns. The late-herbicide, herbicide-only and control treatments do not remove litter and duff. These layers often dry out before the rootlets of germinating pine seeds can penetrate

Table 5. Survival of posthavest pine regeneration by treatment for 1987 and 1988.

Year	Treatment					
	BH	BO	CN	HB	HO	LH
1987	90	88	88	86	80	72
1988	65ab*	56ab	65ab	85a	44b	32b

Dependent variable: arcsine transformation of survival

R^2	C.V.	Root MSE	Mean	Pr > F
0.624649	22.06699	11.25838	51.019	0.0340

* Values with different letters within the same year are significantly different at the 0.05 level of probability.

through to the underlying mineral soil. Both 1987 and 1988 were drought years in middle Georgia. Seedling establishment on unburned plots was therefore confined to areas scarified by logging equipment which resulted in very uneven distribution. No patches of reproduction happened to occur on the belt transects in the late-herbicide plots.

Based on the results of both surveys, we conclude that adequate free-to-grow seedlings are present to ensure the new stands on all treatment plots will contain a significant pine component. The distribution of these seedlings, however, is disappointingly uneven on control, herbicide-only and late-herbicide treatment plots.

Seedling heights at the end of the first and second seasons after treatment did not differ significantly by treatment (Table 4). Pine recruitment continued throughout the measurement period and each seedling was flagged but not individually tagged. Thus plots with many new recruits had many small trees. These trees were not separated in the field from those a year older, so growth of older seedlings was masked by new recruits. Significant height differences were found among FTG classes in 1988, and one would expect seedlings with little competition to be taller than those being subjected to severe competition.

Herbaceous And Vine Response: In the fall of 1987, herbaceous vegetation covered from 32 to 40 percent of the ground surface (Table 6). In the fall of 1988, herbaceous cover of the ground surface ranged from 33 percent on the controls to 58 percent on the herbicde-burn plots. Vines covered an average of 6 percent of the subplots in 1987 and 11 percent in 1988. We expect the coverage of vines to increase at the expense of the herbaceous component over the next few years.

Twenty-two species groups were tallied on the study plots during the fall of 1987. Nutsedges were the most common herbaceous plant, occurring

Table 6. Percent of 1/100 ac subplots stocked with indicator species and the average subplot coverage associated with six preharvest seedbed preparation treatments on the Georgia Piedmont.

		Treatments*						
		BH	BO	CN	HB	HO	LH	Mean
		(percent)						
Bluestems								
Yr 1	Stocking	19	31	45	29	50	33	34
	Cover	02	02	04	01	08	02	03
Yr 2	Stocking	19	38	40	54	46	42	40
	Cover	01	01	03	02	10	02	03
Nutsedges								
Yr 1	Stocking	75	81	55	96	58	58	70
	Cover	11	10	06	10	02	08	08
Yr 2	Stocking	12	0	0	04	0	0	3
	Cover	01	0	0	01	0	0	< 01
Plumegrass								
Yr 1	Stocking	50	50	50	42	62	58	52
	Cover	05	05	05	04	09	07	06
YR 2	Stocking	50	25	30	33	58	58	42
	Cover	04	03	02	03	07	05	04
White eupatorium								
Yr 1	Stocking	81	44	59	92	67	58	67
	Cover	13	04	08	13	09	10	10
Yr 2	Stocking	31	12	0	12	04	12	12
	Cover	02	01	0	03	<01	04	01
Japanese honeysuckle								
Yr 1	Stocking	31	38	36	21	33	17	29
	Cover	01	02	02	01	02	01	02
Yr 2	Stocking	50	38	70	21	67	54	50
	Cover	03	03	06	02	04	04	04
Panicums								
Yr 1	Stocking	0	0	0	0	0	0	0
	Cover	0	0	0	0	0	0	0
Yr 2	Stocking	94	56	85	88	83	75	80
	Cover	29	15	19	30	12	22	21
Muscadine								
Yr 1	Stocking	31	62	55	29	50	50	46
	Cover	03	05	05	01	04	07	04
Yr 2	Stocking	31	38	35	21	42	46	36
	Cover	07	05	13	02	07	06	07
Weeds and grasses								
Total cover								
Yr 1		40	34	32	40	36	40	37
Yr 2		51	34	33	58	46	55	46
Vines								
Total cover								
Yr 1		05	07	07	03	06	08	06
Yr 2		11	09	20	04	12	11	11

* Treatment abbreviations explained in the methods section.

on 70 percent of all subplots followed by white eupatorium (fireweed) on 67 percent of all subplots (Table 6). Plumegrass and muscadine grape occurred on more than 50 percent of the subplots in two treatments. Five species each comprised more than 10 percent of the total herbaceous cover the first post-treatment year: white eupatorium (22 percent); nutsedges (19 percent); plumegrass (14 percent); lespedeza (12 percent); and muscadine grape (10 percent). On a treatment basis, bluestems (21 percent on herbicide-only plots) and paspalum grasses (10 percent on herbicide-burn plots) are added to the above list.

Twenty-three herbaceous species and species groups were recorded during the fall 1988 survey. Nutsedges were only observed on 3 percent of the subplots and fireweed on 11 percent (Table 6). Panicums (including cane-grass) were found on 80 percent of all subplots. Honeysuckle occurred on 50 percent of the study subplots. Plumegrass occurred on over half of the plots in the herbicide-only and late-herbicide treatments and bluestems on over half the herbicide-burn treatment plots. The second year after treatment, panicums (37 percent) and grape (12 percent) each comprised more than 10 percent of the total herbaceous cover. On a treatment basis, goose-grass, comprised 15 percent of the hebaceous cover on the burn-herbicide plots and 13 percent on the late-herbicide plots; honeysuckle 12 percent on the controls; bluestems 17 percent, plumegrass 12 percent and lespedeza 12 percent on the herbicide-only plots.

Non-arborescent Hardwoods: Only four species of shrubs were noted: winged sumac, poison oak, blueberry, and hawthorn. A total of 162 plants were tallied the first year after treatment; 96 of them on the herbicide-burn treatment plots. One hundred twenty-nine of these shrubs were winged sumac, the only species that occurred on more than half the subplots within a treatment. It occurred on 62.5 percent of the subplots on the herbicide-only treatment but still shaded less than 2 percent of the ground.

The shrub component became even less important the following year. A total of 108 plants were recorded; 59 of them were on the herbicide-burn treatment plots. Forty-eight of the stems were blueberries and 47 were winged sumac.

Arborescent Hardwoods And Pine: Twenty-one species groups were recorded in the fall survey one year after logging. Although no species occurred in every subplot, flowering dogwood, sweetgum, and red oaks were found in more than 90 percent of all subplots (Table 2). Pine and cherry occurred in more than 80 percent of the subplots and hickory, persimmon, and elm occurred in more than 50 percent of the subplots. Stem density averaged 8,000/ac. Thirty-four percent (2,700) of these stems were sweet-gum. Flowering dogwood and red oaks also averaged more than 1,000 stems/ac. Eastern redbud exceeded 1,000 stems/ac 1 year after the herbicide-only treatment. Maple, hickory, pine, black cherry, and elm exceeded 500 stems/ac 1 year after at least one of the treatments.

In the fall, 2 years after treatment, 18 species groups were found. Pine and sweetgum occurred on all study subplots (Table 2). Flowering dog-wood and red oaks appeared on more than 90 percent, cherry on more than 80 percent, and elm on more than 50 percent of all subplots. Average number of woody stems/ac of the three major species groups each decreased by about 20 percent resulting in a total of 6,400 stems/ac for all species. Decreases of this magnitude between first and second year hardwood seedlings have been noted in other studies and are thought to simply reflect natural selection processes. Sweetgum continued to dominate the vegetation, now comprising 38 percent of the total number of stems. Two years after at least one of the treatments, maple, flowering dogwood, pine, and red oak numbers all exceeded 1,000/ac. Eastern redbud and black cherry numbers exceeded 500 stems/ac after at least one of the treatments. There is little doubt that sweetgum will dominate the hardwood component of the developing stand with flowering dogwood, red oaks, cherry, and elm as common associates.

The temporary increase in succulent sprouts should attract a wide range of wildlife such as quail, turkey, and deer. Many of the most common plant species groups recorded on the study transects are considered to be of primary wildlife value in middle Georgia (Wade et al., 1989). These species include black cherry, herbs, honeysuckle, red oaks, greenbriars, and muscadine grape.

Summary And Conclusions

A low-intensity late-summer underburn 2 months after "thin line" herbicide treatment was safe and easy to conduct. Establishment of pine seedlings was best on the herbicide-burn treatment but all six treatments provided more than enough FTG class 1 and 2 seedlings to eventually dominate the overstory of the developing stand. The distribution of these seedlings was very uneven on control, herbicide-only, and especially late-herbicide plots.

Seedbeds remained receptive to pine establishment for several years after treatment. The failure to recognize the need to specifically identify new recruits prevented meaningful comparison of any differences in pine seedling height between treatments.

The herbicide treatments used, preserved advance pine regeneration. Before considering the use of fire, advance reproduction should be evaluated including an assessment of the number of stems likely to capture a place in the overstory of the next stand. Variation in pine development within treatments shows the value of site-specific preparation prescriptions over a single generalized prescription for the whole area (see Moorhead and Dangerfield, this volume).

The hardwood component was drastically reduced by all treatments but is rapidly recovering from surviving rootstocks. It appears sweetgum will dominate the hardwood component of the developing stand with flowering dogwood, red oaks, elm, and cherry as common associates. Herbaceous species dominated all treatment plots soon after harvest. The abundance of individual species was treatment specific. Vines were a major component of the surface vegetation prior to harvest and should become so again, especially at the expense of the herbaceous plants, as succession continues. Results demonstrated that: (1) a single preharvest low-intensity summer prescribed fire, by itself or in conjunction with selective herbicide treatment of residual hardwoods is a practical seedbed preparation technique to reestablish southern pine on lower Piedmont mixed pine-hardwood sites; (2) combining the selective use of herbicides with fire can further increase the probability that pine will dominate the canopy of the emerging forest stand; (3) herbicide treatments do not expose mineral soil seedbeds and therefore may result in uneven distribution of pine reproduction; and (4) wildlife values are enhanced, at least temporarily, by these treatments.

Acknowledgments

Authors thank the Georgia Forestry Commission for financial support of this study, and Keith Wilson for providing the study area.

Literature Cited

Bramlett, D.L.; E.P. Jones, Jr., and D.D. Wade. 1991. Herbicide and burn site preparation in the Georgia Piedmont. pp. 138-146, In: Sixth Biennial Southern Silvicultural Research Conference, October 31- November 1, 1990, Memphis, TN: Gen. Tech. Rep. SE-70. Asheville, NC: USDA Forest Service, Southeastern Forest Experiment Station. 868 p.

Chen, Ming-Yih; Earl J. Hodgkins; and W.J. Watson. 1977. Alternative Fire and Herbicide Systems for Managing Hardwood Understory in a Southern Pine Forest. Agriculture Experiment Station, Circular 236, Auburn University, AL. 19 p.

Clason, Terry. 1989. Site preparation treatment options for nonindustrial forestland. Forest Farmer 48(4):16-21.

Edwards, M. Boyd; Dangerfield, Coleman W. 1990. Reliable, low-cost alternatives for pine regeneration in the south. Res. Pap. SE-280. Asheville, NC: USDA Forest Service, Southeastern Forest Experiment Station. 6 p.

Glover, Glenn R.; Dickens, Dale F. 1985. Impact of Competing Vegetation on Yield of the Southern Pines. Ga. For. Res. Pap. 59. 14 p.

Korstian, Clarence F.; Coile, Theodore S. 1938. Plant Competition in Forest Stands. Duke Univ. School of For. Bull. 3. 93 p.

Moorhead, D.J.; Dangerfield, Jr., C.W. 1991. The value of site preparation prescriptions: An economic analysis. pp. 194-201, In: Sixth Biennial Southern Silvicultural Research Conference, October 31- November 1, 1990, Memphis, TN: Gen. Tech. Rep. SE-70. Asheville, NC: USDA Forest Service, Southeastern Forest Experiment Station. 868 p.

Ohmann, Lewis F. 1973. Vegetation data collection in temperate forest research natural areas. Res. Pap. NC-92. St. Paul MN: USDA Forest Service, North Central Forest Experiment Station. 35 p.

Wade, Dale D.; Weise, David R.; Shell, Ronnie. 1989. Some effects of periodic winter fire on plant communities on the Georgia Piedmont. pp. 603-611, In: Proceedings Fifth Biennial Southern Silvicultural Research Conference; 1988 November 1-3; Memphis, TN. Gen. Tech. Rep. SO-74. New Orleans, LA: USDA Forest Service, Southern Forest Experiment Station.

Webb, Charles D.; Hunt, Davie L. 1965. Seed crop estimation in a slash pine seed production area. Georgia Forest Research Paper No. 28, Georgia Forest Research Council, Macon, GA. 5 p.

Zutter, Bruce R.; Glover, Glenn R.; Dickens, Dale F. 1985. Competing vegetation assessment systems in young southern pine plantations. pp. 279-286, In: Proceedings Third Biennial Southern Silvicultural Research Conference; 1984 November 7-8, Atlanta, GA. Gen. Tech. Rep. SO-54. New Orleans, LA: USDA Forest Service, Southern Forest Experiment Station.

Appendix 1. List of plant species found on the study plots

Woody Plants

American holly	*Ilex opaca*	Japanese honeysuckle	*Lonicera japonica*
American hornbeam	*Carpinus caroliniana*	Loblolly pine	*Pinus taeda*
Ash	*Fraxinus* spp.	Muscadine grape	*Vitus rotundifolia*
Black cherry	*Prunus serotina*	Persimmon	*Diospyros virginiana*
Black tupelo	*Nyssa sylvatica*	Poison oak	*Toxicodendron toxicarium*
Blueberry	*Vaccinium* spp.	Red maple	*Acer rubrum*
Eastern hophornbeam	*Ostrya virginiana*	Red mulberry	*Morus rubra*
Eastern redbud	*Cercis canadensis*	Sassafras	*Sassafras albidum*
Eastern redcedar	*Juniperus virginiana*	Shortleaf pine	*Pinus echinata*
Florida maple	*Acer barbatum*	Southern red oak	*Quercus falcata*
Flowering dogwood	*Cornus florida*	Sweetgum	*Liquidambar styraciflua*
Greenbriars	*Smilax* spp.	Water oak	*Quercus nigra*
Hackberry	*Celtis* spp.	White oak	*Quercus alba*
Hawthorn	*Crataegus* spp.	Winged elm	*Ulmus alata*
Hickory	*Carya* spp.	Winged sumac	*Rhus copillina*
Honeylocust	*Gleditsia triacanthos*	Yellow-poplar	*Liriodendron tulipifera*

Herbaceous Species

American burnweed (fireweed)	*Erechites* spp.	Panicums (inc. low panicums)	*Panicum* spp.
Aster	*Aster* spp.	Partridgepea	*Cassia* spp.
Blackberry	*Rubus* spp.	Paspalum grasses	*Paspalum* spp.
Bluestems (broomsedge)	*Andropogon*	Plumegrass	*Erianthus* spp.
Dogfennel	*Eupatorium* spp.	Purple love grass	*Eragrostis* spp.
Elephant's foot	*Elephantopus* spp.	Purpletop grass (grease grass)	*Tridens* spp.
Goldenrod	*Solidago* spp.	Rabbit tobacco	*Gnaphalium* spp.
Goosegrass	*Eleusine indica*	St. Johnswort	*Hypericum* spp.
Lespedeza	*Lespedeza* spp.	Spike grass	*Uniola* spp.
Nutsedges	*Cyperus* spp.	Tickclover	*Desmodium* spp.
White eupatorium (fireweed)	*Eupatorium album*		

United States
Department of
Agriculture

Forest Service

Southeastern Forest
Experiment Station

General Technical Report
SE-70

Proceedings of the
Sixth Biennial Southern Silvicultural Research Conference

Memphis, Tennessee
October 30 - November 1, 1990

Volume 1